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Fragile Environment, Seasonality, and Maternal and Childhood Undernutrition in Bangladesh

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Abstract

Objective: To understand whether spatial and seasonal variations affect maternal and childhood undernutrition in Bangladesh. The study first tests the hypothesis whether agricultural and household incomes are same across different agro-ecological environments. It then carries out an in-depth analysis of the effect of unfavourable ecologies on maternal and child malnutrition.

Design: The study used two sets of data. In order to test the hypothesis whether the performance of agricultural and household incomes are affected by adverse agro-ecologies, a longitudinal data set available for a nationally representative sample has been used. These surveys were planned and implemented by one of the authors of the study. On the other hand, Food Security Nutrition Surveillance Projects (2011 and 2012) were the source of data for the nutrition aspect of the study. Anthropometric indices were used in assessing the nutritional status. The key variables of interest of this study were seasonality and geographical location. General Linear Model, Multinomial and Binary Logistic Regression analysis were done to assess the relationship between the explanatory variables and the nutritional status indicators.

Subjects: The initial sample of the longitudinal data was drawn in 1987; the survey was repeated for the same villages and households in 2000, 2004, 2008, and 2014, which generated a panel data for assessing the changes in rural livelihoods over a long period of time. Furthermore, a total of 17,712 mother-child pairs were included from the Food Security Nutrition Surveillance Project (FSNSP) to assess the impact of unfavourable agro-ecology on nutrition.

Results: The panel data analysis showed that household income is not equal across agro-ecology; the fragility of the environment may thus affect the household's ability to access food, which may have negative influence on the nutritional status of mothers and children. Coastal areas have less dependence on agriculture, particularly on cultivation which diminished over time. Per capita income has been increasing in coastal areas, led by remittance growing at 8 per cent per year against 6 per cent in other areas. Regression analysis shows that a household in coastal zones earns 19 per cent lower than one in favourable zones. Although farm practices are lower in unfavourable areas, the deficiency is compensated by increased non-farm incomes. The results from the FSNSP data found that overall the rate of stunting and wasting prevalence were 36 per cent and 11.7 per cent respectively. Among the mothers, nearly 28 per cent suffered from chronic energy deficiencies. The study found that highly significant regional heterogeneity in undernutrition exists in Bangladesh; alarmingly high levels prevail in the Haor Basin and coastal belt areas. The study also found significantly higher rates of underweight and wasting prevailing in the monsoon season compared to the two harvest seasons (post-Aman and post-Aus) among children under five. Month of birth failed to show any significant association with the nutrition outcome of the children.

Conclusion: In order to determine the most effective strategies for accelerating reduction in undernutrition, it is important that the determinants of undernutrition are known. The findings of this study imply the importance of bringing geographical location and seasonal thinking back into the various current debates on hunger and nutrition.

1. Introduction

Undernutrition among mother and children remains as one of the main public health challenges of the 21st century, particularly in low and middle income countries (Victora 2010). In the review of the Millennium Development Goals, it was pointed out that nutrition was not focused upon appropriately. It now occupies a prominent place in the Sustainable Development Goals (SDG) for 2015-2030 recently approved by the international community. Despite progress, improvements in nutrition still represent a massive unfinished agenda (Black et al. 2013). The overall findings are that 165 million children had stunted growth in 2011, and almost 3•1 million under-five children die every year from undernutrition; that is a staggering 45 per cent of total child deaths in 2011 (ibid.).

The causes of malnutrition are directly related to inadequate dietary intake as well as disease, though many factors contribute to the indirect causes. While most nutrition interventions are delivered through the health sector, non-health interventions can also be critical. Availability and access to sufficient nutritious food produced in the agricultural sector at the national and household levels are among such factors. Agricultural growth and the diversity of food production and consumption thus assume importance as drivers of progress on the nutrition front.

Over the last three decades, technological progress has been the prime mover of the production of foodgrains, particularly the staple foods – rice, wheat and maize. But improved technologies have been developed mostly for favourable ecologies that are characterised by good water control, with existence of facilities for irrigation and drainage (Ruben et al. 2007).Technological progress has reached its limit for these ecologies; as a result the rate of growth in production and productivity of food has slowed down in recent years (Hossain 2007). Although research is in progress, scientists have not been able to develop appropriate technologies for fragile environments like areas that are prone to drought and floods as well as salinity-affected coastal areas. As a result, marginality and ecosystems are now emerging as important development issues (Dasgupta and Mailer 1994; Duraiappah 1998; Krugman 1999). Such differential technological progress across agro-ecologies may have affected production and availability of staple food, which in turn may lead to poverty and malnutrition.

Spatial distribution of poverty in Bangladesh shows that poverty is concentrated in ecologically unfavourable areas (Chowdhury & Christa 2014). Recently, the issue of spatial distribution of undernutrition has emerged as a matter of concern as well, considering the growing evidence of the strong persistence of existing inequalities (Bredenkamp et al. 2014).Therefore, whether ecological differences have affected nutritional outcomes is becoming an important issue for research. Seasonal fluctuation in nutritional status is another important factor influencing poverty and the growth and well-being of children. Seasonality refers to any regular pattern or variation that is correlated with the seasons (Devereux et al. 2012). Seasonality manifests itself in multiple dimensions of livelihoods — employment of workers, food availability, prices, health, access to services, etc. — which affect livelihood opportunities and options (Zug 2006). People adopt different strategies such as migration and access to credit to augment income and consumption during slack seasons. Seasonality is significantly related to food insecurity, with pre-harvest times accompanied by food shortages. In Bangladesh, this situation is described as "monga", and was widely prevalent in the north-western districts, in areas adjacent to the rivers Jamuna and Teesta (ibid.)

The objectives of this study are to understand whether spatial and seasonal variations affect maternal and childhood undernutrition in Bangladesh. The study takes into consideration the effect of other proximate drivers of nutrition such as socio-economic factors and non-food environments, to separate the effect of ecology and season. The study first tests the null hypothesis that agricultural and household incomes are the same across different production environments. It then carries out an in-depth analysis of the effect of unfavourable ecologies on maternal and child malnutrition.

2. Sources of Data and Methodology

2. 1 Agricultural performance across agro-ecologies

In order to test the hypothesis whether agricultural and household incomes are affected by adverse agro-ecologies, we have used a longitudinal data set available for a nationally representative sample. These surveys were planned and implemented by one of the authors of this study. The initial sample was drawn in 1987 for a study of the impact of the "Green Revolution" in Bangladesh and the impact on favourable and unfavourable environments (Hossain 1998). The sample was drawn using a multistage random sampling method. In the first stage, 64 Unions (Bangladesh has 64 districts) were selected randomly from the list of all the Unions (local government units) of the country. In the second stage, one village was selected from each Union, such that the village has characteristics most representative of the particular Union. A census of all households was conducted, and proportionate random samples of 20 households were drawn from each stratum classified by landownership and sources of income. The survey was repeated for the same villages and households in 2000, 2004, 2008 and 2014 to generate a panel data for assessing the changes in rural livelihoods over a long period of time and other relevant issues such as impact of rice research on poverty reduction, poverty mapping, and the impact of commodity price spike on rural poverty (Hossain 2004; Hossain and Bayes 2009; Balagtas et al. 2014). In 2000 and 2014, the sample was redrawn with 30 and 40 households, respectively, to make the sample representative for those years. The households were classified using the wealth-ranking method.

In order to assess agricultural performance across production environments, the sample households were divided into three ecosystem groups: a) flood-prone, b) salinity-affected coastal areas, and c) favourable (as control). The flood-prone environment includes villages that are flooded every year because of overflowing of the adjacent major rivers as well as the depressed basins where crop farming is not possible during the monsoon season (June to November) as they remain under water for more than six months. The coastal ecosystem covers villages where rivers and canals are subjected to tidal surges from the sea and the area is affected by water and soil salinity during the dry season. The favourable ecosystem includes all other villages in the sample. The household income and its components were compared across the ecosystems. A multiple regression model was estimated using the usual determinants of income, and the fragile environments were included as dummy variables to separate out the effect of fragility on household income. The model is estimated by the 'Robust' method using the software STATA.

2.2 Nutritional status and independent variables in the model

The nutrition aspect of the paper is based on data generated by the Food Security Nutrition Surveillance Project (FSNSP) implemented by the Helen Keller International (HKI) and the James P. Grant School of Public Health (JPGSPH) of BRAC University, in partnership with the Bangladesh Bureau of Statistics. The project started generating data from 2010 and was planned to continue to 2015. Every year FSNSP conducts three rounds for data collection from six distinct agro-ecological zones, in addition to acquiring samples from the remaining areas of the country. FSNSP data are available for the years 2010, 2011 and 2012. FSNSP 2010 variables are different from FSNSP 2011 and 2012; hence this study only included analysis of data of FSNSP 2011 and 2012.

Nutritional status was assessed by several anthropometric indicators of mothers and children. The two key anthropometric measures for children were weight-for-height and height-for-age. These measures were expressed in the form of Z-scores — WHZ (weight-for-height) and HAZ (height-for-age) —generated by using the software WHO Anthro. The Z-scores of the children were analysed as continuous as well as categorical variables. The usual Z-score cut-off of -3.00 SD was used for classifying a child as severely wasted or stunted and -2.00 SD as wasted or stunted. For assessing maternal nutritional status, body mass index (BMI) was calculated and was graded into six groups of chronic energy deficiency (CED): grade III (<16.00), grade II (16.00-16.99), grade I (17.00-18.49), normal (18.0-24.99), pre-obese (25.00-29.99) and obese (≥30.00), using the international WHO cut-offs (WHO 2000). Six further categories of BMI were also used, according to international Asian cut-offs, where the CED levels were similar to WHO cut-offs, but ranges for normal and pre-obese were lowered as 18.50-22.99, 23.00-27, and 49, respectively (WHO 2004).

From FSNSP 2011 and 2012 data, households with children under five were included first. Children and mothers without data on height, weight, age or sex information were excluded. Anthropometric measurements of above or below four standard deviations from the mean for the mothers were considered as outliers and so excluded from the analysis (Nestel et al. 1991) For Z-scores, the cut-offs recommended by WHO for data exclusion were used; thus, data were excluded if a child's HAZ was below –6 or above +6, and WHZ was below –5 or above +5, because these extreme values were most likely a result of errors in measurement or data entry (WHO 2006). Lastly, those children and women were excluded, for whom information on the selected socio-economic and demographic variables of the study was lacking. . Ultimately, a total of 17,712 mother-child pairs, whose records were complete in the required individual and household level variables, were included in the analysis (**Appendix I**).

The key variables of interest in this study were seasonality and geographical location. In the data set, three rounds of collection of information represent seasonality which has been divided into three categories: a) post-Aman harvest period (January-April), b) height of the monsoon (May-August), and c) post-Aus harvest season (September-December), where Aman and Aus are two popular and chiefly cultivated varieties of rice in Bangladesh.

The months of birth of children were analysed as individual month variables and also categorised into three 'birth-season' variables as a) January-April (post-Aman harvest), b) May-August (monsoon) and c) September-December (post-Aus harvest).

To assess regional inequality, data were collected from different agro-ecological locations in the Food Security Nutrition Surveillance Project (FSNSP), namely, coastal belt, eastern hills, Sylhet Haor Basin, flood plains (active lower, active upper and northwest). These categorisations were based on factors such as tendency to natural disasters, distribution and quality of land, access to education and health facilities, level of infrastructure development, and employment opportunities. Role of dietary diversity and a household's food security level were also assessed, with dietary information of the household taken into account for the previous 24-hour period. Foods were categorised into nine groups, e.g., grains, meat, fish, milk, eggs, vegetables, dals (legumes), green leafy vegetables and fruits (vitamin A-rich and others). Households consuming less than five groups were considered as 'low diversity group' and the others as 'high diversity group'. The Household Food Insecurity Access Scale (HFIAS) was constructed by the guideline proposed by Coates et al. (2007). HFIAS is a brief survey instrument developed by Food and Nutrition Technical Assistance (FANTA) to assess whether households have experienced problems with accessing food during the last 30 days. HFIAS poses questions of increasing concerns on food security domains, such as anxiety over food, insufficient dietary quality, and the quantity of food available. A food-secure household experiences none of the food insecurity (access) conditions, or just experiences worry, even that rarely. A mildly food-insecure (access) household worries about not having enough food sometimes or often, and/or is unable to eat preferred foods, and/or eats a more monotonous diet than desired and/or some foods considered undesirable, but only rarely. But it does not cut back on quantity nor experience any of the three most severe conditions (running out of food, going to bed hungry, or going a whole day and night without eating). A moderately food-insecure (FI) household sacrifices quality more frequently, by eating a monotonous diet or undesirable foods sometimes or often, and/or has started to cut back on quantity by reducing the size of meals or number of meals, rarely or sometimes. But it does not experience any of the three most severe conditions. A severely food-insecure (FI) household has worsened to often cutting back on meal size or number of meals, and/or experiences any of the three most severe conditions (running out of food, going to bed hungry, or going a whole day and night without eating), even if only infrequently or rarely. In other words, any household that experiences one of these three conditions even once in the previous four weeks (30 days) is considered severely food insecure(Salvador Castell 2015).

Other socio-economic and demographic information that were controlled for in the study were residence (rural/municipality/city Corporation), education and occupation of the woman member as well as of the main earner of the family, and wealth index of the household. The wealth index was created by using the principal component analysis technique, which is explained elaborately in the DHS Comparative Reports No. 6, The DHS Wealth Index (Rutstein & Johnson 2004).Additional variables like a household's involvement with agricultural activities, vegetable production and livestock rearing were included as binary variables having 'yes' or 'no' categories.
All continuous data were checked for skewness by z-test of coefficient of skewness divided by standard error of skewness, as well as examination of the mean-median difference and the frequency distribution with a normal curve. The relationship between two categorical variables was analysed by chi-square test and continuous data by independent sample t-test. One-way analysis of variance (ANOVA) was used in comparing the means of three or more groups. Curve estimation was applied where necessary and linear and quadratic effects of the continuous independent variables were included in the model. General Linear Model (GLM) or multiple regression models were used to analyse dependent continuous variable with two or more independent variables. When the Z-scores and maternal BMI were analysed as categorical variables, logistic regression analyses, binary or multinomial, were undertaken with the socio-economic and demographic variables. Sequential models were mainly used in the analyses; for each dependent variable adjustment was made for periods of survey, linear and quadratic effects of age and all the other explanatory variables in the model, e.g., residence, education and occupation of the woman member and the main earner, wealth index, dietary diversity group, etc. Level of significance was taken at $p \leq 0.05$. Bonferroni corrections, both strict and sequential, were applied to correct for the number of statistical tests undertaken. SPSS version 20 was used for all statistical analysis.

3. Results

Before we discuss agricultural performance, it would be pertinent to shed light on a few socio-economic and demographic aspects relating to the sample households.

3.1 Demographic profile

Table 1 presents information about family size. The average family size in Bangladesh has depicted a downward trend since independence in 1971, due to a host of factors such as spread of family planning activities, awareness about small family, declining infant mortality rate, participation of women in economic activities, etc. The current household size is 4.2 at the national level. In agro-ecological zones, a declining trend in family size is in evidence, from 5.9 in 1988 to 4.3 in 2014. However, the unfavourable zones (flood-prone and coastal) continue to depict relatively larger family sizes than the favourable zone, although here also there has been a decline over time. This is possibly due to low awareness, lack of rigorous family planning activities, etc.

3.2 Education of household heads

Table 2 presents information on education of household heads across ecological zones. In this respect, we sought two pieces of information from respondents: access to formal education by household heads and the number of years in school. The proportion of household heads with no formal education continues to be the highest in flood-prone zones (around 50 per cent) and the least in the coastal areas. However, this has declined over time across regions. Again, the household heads in coastal zones have spent more years in schools (5.7) than others, although this has increased over time across regions.

Panel data also show that enrolment in primary schools has increased tremendously over the last four decades in all zones (Table 3), with coastal zones continuing to lead others in primary and secondary school enrolment. However, in all types of schools, flood-prone zones perform the worst, due to communication and infrastructural bottlenecks.

3.3 Occupation of household heads

Table 4 presents information on occupational shifts of household heads across ecosystems. About half of household heads took up cultivation as an occupation in 1988; in 2014 the share dropped to one-third. At disaggregated level, and quite obviously, favourable zones had more in cultivation than others and coastal zones had the least. The differences could be attributed to fluctuations in yield followed by early flood or intrusion of saline water. The second discernible change is in the area of agricultural labour. Almost one-fourth of heads in favourable and flood-prone zones and one-fifth in the coastal belts were employed in agriculture in 1988; the share reduced to one-tenth in the former and just 7 per cent in the latter. This seems to be in line with the national trend of reduction in agricultural work in the wake of growing tenancy market, non-farm activities and migration.

3.4 Land ownership, farm size and technology adoption

As can be observed from **Table 5**, the average size of owned land has sharply decreased over time to perk at 0.40 ha— close to the national average. Land size has decreased more in favourable zones, from 0.63 ha in 1988 to 0.38 ha in 2014. In 2014, land size was highest in flood-prone zones. The distribution of farm households was 61 per cent in favourable zones compared to 54 per cent in flood-prone and coastal zones. It is not surprising that favourable zones will have more farm households compared to others as the latter group tends to face a host of constraints to agricultural production such as early flood, saline water, etc. Again, like owned land, farm size has almost halved in all areas, from roughly 0.90 ha in 1988 to about 0.52 ha in 2014. Noticeably, farm size in favourable zones reduced more sharply than in the unfavourable zones.

Rice covers roughly three-fourths of cropped area in all the zones and marginally declined in all the areas, with the exception of the coastal belt that witnessed sharp decline possibly due to intrusion of saline water. For example, in 1988, more than four-fifth of cropped area was covered by rice; in 2014, the share fell to three-fourth. Farm households' access to irrigation has sharply increased for favourable and flood-prone zones. Almost all households in the favourable zones and 90 per cent in flood-prone zones have access to irrigation now. However, it is only 50 per cent for coastal zones — up from 34 per cent in 1988. It is thus not surprising that only two-third of rice area in the coastal zones is covered by modern varieties (MVs) as against over four-fifth in favourable and flood-prone zones. Finally, in 2014, cropping intensity was highest in favourable zones (168) as against roughly 142 in unfavourable zones.

3.5 Capital accumulation

Table 6 presents information on capital accumulation. It is interesting to observe that in households in coastal areas capital endowment increased three-fold, from $ 371 in 1988 to $1511 in 2014, followed by those in the favourable zones. However, increase in non-agricultural capital was much faster in coastal zones than in others.

3.6 Household income: Structure and growth

The most dramatic change in income structure occurred in the coastal zones. For example, in 1988, agriculture comprised roughly 60 per cent of household income but the share almost halved in 2014 (**Appendix II**). Special mention may be made that income from rice, which was an important source back in 1988, drastically reduced. On the other hand, the share of non-agricultural income rose from about 56 to 70 per cent during the same period of time. The share of remittance income also shot up from about 8 per cent to about 30 per cent over time. It may be mentioned that such changes also happened in the other zones but not as sharply as in the coastal zones.

The growth of household income is presented by **Table 7**. Per capita income grew at 3 per cent in the favourable and coastal zones in the early decades (1988-2000) but only at 1 per cent in flood-prone zones. In recent periods (2000-2014), per capita income rose by over 6 per cent in all the zones. Over a long-term period, per capita income growth exceeded 4 per cent. At disaggregated level, agricultural income grew at negative rates in all areas during 1988-2000 but picked up quite well during 2000-2014. This means that the improvement in growth rates of per capita income can be adduced mostly to the growth of non-agricultural income.

3.7 Determinants of income

The data presented in Table 9 show that both flood-prone and coastal ecosystems have substantial lower agricultural income. But the households in the coastal ecosystem overcome most of the disadvantages through higher non-farm incomes from higher non-land fixed assets, higher educated workers, and higher incidence of overseas migration of workers. So the difference in household income is only marginal. In the flood-prone ecosystem, non-agricultural income is also lower compared to the favourable ecosystem, because of lower average years of schooling of the worker and lower value of non-land fixed assets. The households in the flood-prone ecosystem also avail of the opportunities of overseas migration, but to a much less extent than the households in the coastal ecosystem.

It is postulated that household income will depend on the endowment of land, renting of land from the tenancy market the value of agricultural and non-agricultural fixed assets, the number of earning members and their level of schooling. Female-headed households may have a disadvantage and earn less, while households receiving remittances from migrant members within the country and overseas will have higher income. The variable "access to electricity" was introduced to assess the effect of development of infrastructure. In fact, the villages which have electrification also have connections to paved roads. The regression model helps to assess the effect of unfavourable ecologies which are introduced in the model as dummy variables after dissociating the effect of variations in factor endowments, infrastructure development and migration of members that should be independent of the agro-ecology (**Appendix III**).

The findings indicate about 70 per cent of variation in income among sample households. The coefficients of all variables are statistically significant, except female headship and the households having migrant members working within the country. The female-headed household is now a mixed bag consisting of widows and separated women, as well as women taking management responsibility after their husbands migrated to work in towns and overseas. The latter group is economically better off than the former.

The value of the coefficient shows that a household earns on average US$ 1138 from an acre of land under its ownership. If the land is rented, the return is lower by about 10 per cent due to the payment of rent to the landowner. The rate of return on capital is about is 28 per cent in agricultural and 24 per cent in non-agricultural pursuits. A male worker earns on average US$252 (US$ 2.22 per day) per year, assuming an employment of 5 days per week). A female worker earns US$ 389. A year of schooling gives a return of US$ 27 for the male worker and US$ 35 for the female workers. If the household has a relative working abroad, the remittance sent augments household income by US$2,455 (also 98 per cent of average household income).

The coefficients of the dummy variables representing the fragile environment are negative and statistically significant. A household living in the flood-prone ecosystem earns on average US$ 331 per year /capita (16 per cent) less than a household living in a favourable environment. For the households in the coastal saline environment the income is lower by US$ 419 (19 per cent) per year/per capita. Thus the null hypothesis that household income is equal across agro-ecologies is not validated by the survey data.

3.8 Poverty situation

The poverty situation across ecological zones is shown in **Table 10**. It appears that incidence of poverty under headcount declined in all areas over time. This is in line with the national average. Also, other measures of poverty in the areas under review declined too.

3.9 Effect on maternal and child malnutrition

Analysis of FSNSP data found that with WHO cut-offs, overall 61 per cent of the Bangladeshi mothers' BMI fell in the normal range, the prevalence of CED was 28 per cent and overweight was 11 per cent. When Asian cut-offs were used, 50.4 per cent and 21.6 per cent of women were normal and overweight, respectively. The results from the pooled data found that the stunting rate was 36 per cent in the 0-59 month-old children, of whom 8 per cent were severely stunted. Underweight and wasting prevalence were 37 per cent and 11.7 per cent, respectively; 10 per cent were severely underweight and 1.1 per cent were severely wasted.

The prevalence of CED and overweight/obesity did not vary substantially from one season to another. The prevalence of CED ranged from a low of 27.2 per cent in the post-Aman harvest period to a high of 28.7 per cent in monsoon time; while the prevalence of overweight/obesity was almost the same in all the three seasons (11 per cent to 11.3 per cent). It was found that just above 13 per cent of the mothers were short according to international standards (height below 145 cm) over this period and the same percentage of mothers' MUAC (mid upper arm circumference) was below 220 mm. When the rates of stunting and wasting of children under five were compared between the three seasons, significantly higher rates of underweight and wasting were observed in the monsoon season compared to both post-Aman and post-Aus harvest seasons (**Figure 1**). The percentage distribution of undernourished mother and children in the different agro-ecological zones are presented in **Figures 2 and 3**; the percentages of all forms of undernutrition in both mothers and children were significantly higher in the Haor Basin areas compared to other parts of the country.

General Linear Model (GLM) (not shown in the Tables) analysis found regional variations for maternal BMI; mothers from the Haor Basin had the lowest mean value. Average BMI of the mothers from the coastal belts was also lower compared to that of mothers from other parts of the country. Mothers living in food-secure households had, on average, a better BMI than those living in food-insecure households. After controlling for the other demographic and socio-economic variables, it was found that educational level; wealth quintile and HFIAS score were strongly associated with BMI values. As educational level of mothers' increased, so did their mean BMI and the difference between richest and poor households were 1.5 kg/ m2. However, seasonality and households' involvement with agriculture or livestock rearing or possession of a homestead garden failed to show any association with maternal BMI.

After correction for the other demographic and socio-economic variables, it was found that unfavourable agro-ecology and seasonality were associated with the Z-scores of children. After controlling for all the other socio-economic and demographic variables, average Z-scores (HAZ and WHZ) were found lowest in the Haor Basin area. Seasonal heterogeneity was present with highest WHZ mean in the post-Aman harvest period, and lowest in the monsoon season. Seasonality was found significant for HAZ score which was slightly higher in the monsoon season compared to the harvest seasons. The difference in the HAZ score between children having and not having diversified diets and between food-secure and severe food-insecure households was significant; as the food security score in a household increased, so did the child's mean HAZ score. Other socio-demographic factors associated with Z-scores were educational level of parents and wealth index. Upward trends in the mean of all Z-scores were evident from low to higher education of parents and from poor to rich households. Children from households where the main earners were agricultural labourers showed significantly lower WHZ scores compared to those households where the main earners were farmers/ professionals. General Linear Model analysis was done for two years in FSNSP by the month of birth for children in the pooled sample, to assess the changes in HAZ and WHZ scores. HAZ or WHZ scores of children did not vary by their months of birth (**Figures 4 and 5**). The mean scores of HAZ were -1.48, -1.46 and -1.45 in the post-Aman harvest, post-Aus harvest and monsoon seasons, respectively (F=0.92, ns); whereas mean WHZ values in theses seasons were -0.86, -0.85 and -0.87, respectively (F=0.65, ns).
Multinomial logistic regression analyses were undertaken to determine whether it was possible to predict the maternal nutritional status based on three levels of maternal BMI (underweight, normal and overweight) using all the socio-economic and demographic variables. The odds ratios obtained from the model (**Table 12**) showed that mothers from the Haor Basin were nearly one and half times more likely to be underweight compared to those from other parts of the country. Those from coastal belt areas also showed more likelihood to be underweight. Seasonality failed to show any association with the nutritional status indicator of mothers. Dietary diversity, unexpectedly, did not show any association with maternal BMI, whereas using HFIAS it was found that mothers from

food-secure households showed less likelihood of being underweight and more likelihood of being overweight compared to others from food-insecure households.

Table 13 presents the results of the binary logistic regression analyses that were undertaken to see how well the socio-economic and demographic variables predicted underweight, stunting and wasting. Children measured in harvest seasons (post-Aman and post-Aus) showed less likelihood of being wasted compared to children measured in the monsoon season. Unexpectedly, month of birth (not shown in Table) or birth-season failed to show any association with any of the Z-scores (**Table 13**). The odds of being stunted was significantly higher among the children from the Haor Basin compared to those from other parts of the country, even after controlling for other factors. Children having low dietary diversity in their household showed more likelihood to be stunted compared with children having high dietary diversity in their households; whereas children from food-secure households showed significantly lower likelihood to be undernourished of any kind — stunted or wasted. After adjustment for the other socio-economic and demographic variables, children of less educated parents and from households having lower wealth index showed more likelihood to be stunted compared to their better-off counterparts. Children of households where main earners were agricultural labourers also showed more likelihood to be stunted compared to children from households where main earners were farmers owning land.

4. Discussion

The risk factors of malnutrition are multifaceted and complex, and the relative importance of each of the known risk factors of malnutrition is likely to vary between settings and hence has to be examined. The panel data analysis in the first part of the paper showed that household income is different across agro-ecologies. The fragility of the environment may affect the household's ability to grow food, which may in turn influence nutritional status negatively. But, entitlement arising out of the growth of non-agricultural — especially remittance — income could help access to food. Hence, giving higher priority to development interventions for these ecologies can help substantial improvement in food security and nutrition at the national level.

The results from the pooled data of 2011 and 2012 found that the rates of undernutrition among children and their mothers were still unacceptably high, although a recent cross-country study by Headey (2013) concluded that from 1997 to 2007 Bangladesh recorded one of the fastest prolonged reductions in child underweight and prevalence of stunting in recorded history, 1.1 and 1.3 percentage points per annum, respectively. Stunting rate was found to be 36 per cent (8 per cent were severely stunted). Underweight and wasting prevalence were 37 per cent (10 per cent severely underweight) and 11.7 per cent (1.1 per cent severely wasted), respectively. Among mothers, nearly 28 per cent suffered from chronic energy deficiencies, while 3.2 per cent of them had a BMI less than 16 kg/m2.

Recently, the issue of spatial distribution of undernutrition has emerged as a matter of urgent concern, considering the growing evidence of wide regional variations within countries (Spray et al. 2013). A recent study in India found that there was an increasing concentration of child malnourishment in certain spatial areas, described as "pockets of concentration" of malnourishment (Nair 2007) Interestingly enough, even in countries like the United States and Malaysia, malnutrition-loaded regions still do exist, where most of these regions are populated by ethnic minorities and are spatially distanced from major urban centers (Slifkin et al. 2000). So it is not surprising that similar pockets would be here in Bangladesh as well, where the haor and coastal belt areas are geographically distinct from other parts. In this study, the overall prevalence of stunting ranged from 46.6 per cent in the Haor Basin to 30.9 per cent in other parts of Bangladesh, whereas the prevalence of underweight ranged from 44.5 per cent in the Haor Basin to 34.1 per cent in other areas. Floodplains had the highest prevalence of wasting (12.4 percent) and the eastern hills had the lowest (10.6 percent). Regional heterogeneity in mean Z-scores was present, as well. Children from the Haor Basin had the lowest mean in the Z-scores. Highest prevalence of maternal underweight (41.6 percent) and lowest mean maternal BMI were also observed in the Haor Basin area. The findings of the present study undoubtedly revealed that, in order to decrease inter-regional disparity, the Haor Basin area needed the most attention from policy makers.. “Haor” is characterised by a bowl or saucer shaped tectonic depression that gets submerged from run-off rainwater from the upstream and remains under water for more than six months of the year. Flash floods due to upstream water destroy the standing crop and thus affect the poor and marginal farmers who earn their livelihood from agriculture. Even during the dry season, due to the increase in evaporation rate and decrease in groundwater level. Cultivation of winter crops and aquaculture is prohibited. Villagers remain isolated with poor road accessibility and transportation links that may have implications for poor access to health facilities and other welfare services (Kandala et al. 2009). These issues deserve closer attention: this study is merely able to highlight the important spatial patterns of undernutrition without being able to fully explain them. To alleviate such pockets of undernutrition, experience from India could be shared; for example, Nair (2007) emphasises several other societal features such as poverty, lack of education, and social characteristics of people (social class, caste, and religion).

The chief objective of this report is the need to place seasonality firmly as the prime factor in the agenda.The findings of previous studies that have investigated the association between seasonality and nutritional status of adults and children have reported inconsistent outcomes. In a study conducted in Ethiopia, children registered better WHZscores in a period before harvest compared to a period after harvest, while the pattern observed for adults was as expected — a higher average BMI was reported in the season of plenty and a lower average BMI in the lean season (Ferro-Luzzi et al. 2002). On the other hand, a Kenyan study did not find significant seasonal differences in children’s mean weight changes but the percentage of children stunted was higher during the lean season (51 percent) compared to the post-harvest months (28 percent) (Kigutha et al. 1995). Other studies have compared children’s nutritional status between the wet and the dry seasons and have found that the children were more likely to have poorer nutritional status in the dry season compared to the wet season (Chikhungu and Madise2014). The present study found significantly higher rates of wasting prevailing in the monsoon season compared to the two harvest seasons (post-Aman and post-Aus); whereas, no difference in maternal BMI was found across three seasons. Contrariwise, in the monsoon season,the average HAZscore was found better compared to the other two seasons. In countries like Bangladesh, dependence on rain- fed agriculture creates variation in food availability across seasons. Periods after harvest are abundant with food while cropping periods have less food. Moreover, the reduced child care during the busy harvesting period could be a potential contributor to the poor HAZ scores during this period — this needs further exploration. In countries like Bangladesh, seasonality in nutrition cannot merely be a food problem. There is growing evidence, globally and in Bangladesh, that environmental enteropathy is a major cause of undernutrition (Lin et al. 2013).. Countries in South Asia that have acombination of very heavy monsoons and high population density provide perfect conditions for water-borne diseases. Further evidence of this is that even though rice production and consumption have increased rapidly in Bangladesh, including production of dry season, irrigated Boro crops that ought to stabilise food consumption throughout the year, wasting has not really gone down. Moreover, wasting is very prevalent, and still very seasonal, even in urban areas, despite little evidence of seasonal fluctuations in wages or food prices. So the complex interplay of seasonality must come into the global agenda of nutrition. As a starting point, governments and NGOs need a thorough understanding of the ways in which seasonality interplays with the underlying causes of undernutrition. Detailed seasonal analysis will enable national governments, donors and other stakeholders to better understand the seasonal nature of undernutrition and implement appropriate policies and practices to build communities' resilience to nutrition crises.

Research has consistently shown that the month of birth is an important predictor of health outcomes, morbidity and mortality. A previous study in India has found that children born during the monsoon months had lower anthropometric scores compared to children born during the fall-winter months. The results emphasised the importance of seasonal variations in environmental conditions at the time of birth in determining health outcomes of young children in India (Lokshin & Radyakin 2012). Unexpectedly, the current study failed to show any association of month of birth with the anthropometric indices of the children.

Drawing results from analysing FSNSP data, this study found that food insecurity of households affected the nutritional status of children under five and their mothers. The effect of food insecurity remained strong even after controlling common and significant socio-economic characteristics like educational status of parents, their working status, wealth quintiles, etc. Therefore, intervention should be taken to eradicate food insecurity. A comprehensive National Food Policy developed in 2008 was followed in 2011 by the Country Investment Plan, which provides stakeholders with a clear roadmap for investment in agriculture, food security and nutrition (Hasan et al. 2013). Following the guidelines, policy makers and programme managers should play a vital role in reducing childhood and maternal undernutrition by implementing necessary interventions focusing on the underlying causes of food insecurity in order to develop a healthy nation as well as improve the overall progress and development of Bangladesh.

From the age of six months onwards, children require a diversified diet that will supply the full range and quantities of nutrients required to support rapid growth (Allen et al. 1991).(Low dietary intake of micronutrients has negative consequences for children's growth and development and for women's health and productivity. In the present study, more than half (55 percent) of children aged six months to five years, a crucial age for development, were from households that did not meet the minimum dietary diversity criteria (at least four food groups per day).Among the causes of undernutrition, the study identified lack of dietary diversity as a key problem. Previous surveys have reported that households consume low-quality diets with little diversity because they lack the resources to grow or purchase micronutrient-rich foods (Torlesse et al. 2004). The drastic increase in food prices since 2007 has additionally contributed to worsen the food security and economic situation of the country (Matin et al. 2009).
Among other socio-economic and demographic factors, this study found robust relationships between the wealth index and education of mother and Z-scores of children. The findings suggest that if undernutrition is to be reduced as specified in various strategic health objectives and the SDGs, policies and strategies for poverty alleviation, promotion of education for mothers and provision of basic sanitation facilities are crucial issues which need to be pursued because they have a big impact on nutritional status.

Limitations of this study included lack of information on consumption of energy intake, macro and micronutrients, and physical activity, which were crucial components in estimating the nutritional status. The cross-sectional nature of data did not allow drawing causal inferences. The findings of this study were weakened by the fact that some unobserved factors were not taken into consideration because of unavailability of information or higher missing values (e.g., information on a number of household factors including childcare practices, food taboos, management of illness, etc.).

8. Conclusion

In order to determine the most effective strategies for reducing the burden of undernutrition and accelerating development, it is important that the determinants of undernutrition are known, especially in the context of unfavourable areas, such as the Haor Basin.There exists highly significant regional heterogeneity in undernutrition in Bangladesh; alarmingly high levels are still prevailing in the Haor Basin and coastal belt areas. It appears that though per capita income has increased overtime, it is not yet translated into the consumption of nutrient-rich diversified foods. Hence, an appropriate policy guideline that focuses on altering the nutritional intake among poor children, especially in the regions with higher prevalence of childhood undernutrition, is needed; more focused programmes targeting specific issues like ‘diversified diet at low cost’ should be implemented and evaluated. A study done on the Nutritional Surveillance Project (NSP) of 1992 and 2000 data by Torlesse et al. (2004) reveals association of rice expenditure with nutritional status of children and concluded that macroeconomic food policies that kept the price of food staples low could contribute toward reducing the percentage of undernourished children; this low price allowed households to spend more money on non-rice foods, and thereby diversify their diet by consuming non-rice foods more frequently (Torlesse et al. 2003). For greatest effect, Miller et al. (2013) suggest that intervention strategies have to be seasonally related. Health workers need to recognise the complex interplay of seasonality in order to find a mix of interventions to address this problem. This paper demonstrates the importance of bringing seasonal thinking back into the various current debates on hunger and nutrition. Food availability and food security issues came out as major concerns for Bangladesh which have direct impact on nutritional status. Education (especially of females) should still be one of the key policy options to achieve the SDG on undernutrition in Bangladesh.The research indicates that more rigorous work is needed to understand seasonality, agriculture and nutrition to develop contextual relevant interventions.

Table 1: Family size (number)

Agro-ecology	1988	2000	2014
Favourable	5.8	5.0	4.2
Flood-prone	6.0	5.6	4.5
Coastal	6.1	5.5	4.4
Total	5.9	5.3	4.3

Table 2: Education of household head, 2014

Agro-ecology	Education of household head					
	No formal education (%)			Average education (years)		
	1988	2000	2014	1988	2000	2014
Favourable	49.8	41.8	36.9	3.1	2.4	4.1
Flood prone	60.5	48.4	44.7	3.9	3.2	4.9
Coastal	33.1	32.8	26.7	4.6	3.6	5.7

Table 3: Schooling rate by age and agro-ecology

	1988	2000	2014
Primary age group (6-10 years) (%)			
Favourable	62.2	87.0	96.2
Flood-prone	58.0	86.7	94.0
Coastal	72.5	92.6	100.0
Secondary age group (11-16 years) (%)			
Favourable	57.6	67.9	82.0
Flood-prone	67.4	66.8	78.1
Coastal	69.0	68.4	86.2
Tertiary age group (17-22 years) (%)			
Favourable	26.1	32.7	49.8
Flood-prone	20.4	26.6	43.0
Coastal	34.5	34.8	47.7

Table 4: Occupation of household head

Occupation (%)	Year 1988			Year 2000			Year 2014		
	Favourable	Flood prone	Coastal	Favourable	Flood prone	Coastal	Favourable	Flood prone	Coastal
Cultivation	46.7	45.1	41.6	43.3	43.6	34.4	37.5	38.1	34.1
Other agriculture	0.2	2.2	0.4	1.1	2.8	2.8	1.6	3.3	2.0
Agricultural labour	26.1	26.6	19.5	13.9	13.2	10.3	10.4	9.9	6.9
Business trade	8.9	10.1	8.2	14.6	12.3	16.2	12.4	10.9	15.6
Service	7.0	6.7	17.5	10.7	10.6	19.5	7.3	4.6	9.9
Non-agricultural labor	6.5	5.9	8.6	13.5	13.4	14.9	12.3	12.7	7.9
Inactive	4.7	3.4	4.3	3.0	4.1	2.1	18.5	20.4	23.5

Table 5: Land ownership, operation and technology adoption

Description	Year 1988			Year 2014		
	Favourable	Flood prone	Coastal	Favourable	Flood prone	Coastal
Own land (ha)	0.632	0.586	0.591	0.376	0.433	0.349
Farm household	68.2	67.5	60.7	60.8	54.8	53.8
Farm size (ha)	0.892	0.803	0.908	0.494	0.564	0.525
Rice area as % of cropped area	74.0	76.9	85.8	71.0	77.3	75.9
Farm household access to irrigation	51.1	40.7	34.0	98.7	90.7	50.3
Irrigated area as % of cultivated area	26.6	20.7	19.3	96.1	85.4	42.1
MV rice area as % of rice area	36.7	27.4	33.4	85.7	86.5	63.7
Crop intensity	164.0	167.1	180.1	167.8	141.0	142.1

Table 6: Type of capital (US $)

Description	Capital			Agricultural capital			Non-agricultural capital		
	1988	2000	2014	1988	2000	2014	1988	2000	2014
Favourable	323	525	1322	145	162	385	178	363	937
Flood prone	288	351	1095	148	173	318	139	178	777
Coastal	371	644	1511	180	143	262	191	501	1249

Table 7: Income (in US $) and income growth of major sources

	Income from sources (US $)			Growth rate/year		
	1988	2000	2014	1988-2000	2000-2014	1988-2014
Household income						
Favourable	1039	1177	2411	1.0	5.1	3.2
Flood prone	991	1025	2105	0.3	5.1	2.9
Coastal	1103	1349	2332	1.7	3.9	2.9
Per capita income						
Favourable	172	246	612	3.0	6.5	4.9
Flood prone	171	193	492	1.0	6.7	4.1
Coastal	180	245	561	2.6	5.9	4.4
Agricultural income						
Favourable	585	519	971	-1.0	4.5	1.9
Flood prone	555	467	790	-1.4	3.8	1.4
Coastal	629	461	696	-2.6	2.9	0.4
Non-agricultural income						
Favourable	455	658	1441	3.1	5.6	4.4
Flood prone	436	558	1315	2.1	6.1	4.2
Coastal	474	887	1636	5.2	4.4	4.8
Remittance income						
Favourable	92	150	524	4.0	8.9	6.7
Flood prone	95	155	533	4.1	8.8	6.6
Coastal	82	218	668	8.1	8.0	8.1

Table 8: Gini coefficient and relative contribution from major income sources

Income source and ecology	Gini coefficient			Relative contribution of sources (%)		
	1988	2000	2014	1988	2000	2014
Agricultural income						
Favorable	0.345	0.359	0.307	41.5	31.9	29.5
Flood prone	0.287	0.320	0.255	42.1	36.8	25.3
Coastal	0.298	0.349	0.206	45.5	25.0	16.7
Non-agricultural income						
Favourable	0.626	0.604	0.493	58.4	68.1	70.5
Flood prone	0.503	0.459	0.453	57.9	63.2	74.7
Coastal	0.474	0.544	0.438	54.5	75.0	83.3
Remittance income						
Favourable	0.838	0.733	0.654	15.8	18.8	34.0
Flood prone	0.419	0.560	0.619	10.5	21.4	41.4
Coastal	0.614	0.603	0.584	12.3	20.4	45.4
Per capita income						
Favourable	0.449	0.509	0.458			
Flood prone	0.440	0.428	0.420			
Coastal	0.387	0.476	0.407			

Table 9: The effect of unfavourable environments on household income (US$): estimates from a multivariate regression model

	1988			2000			2014		
Drivers	**Co-efficient**	**t-value**	**Significance**	**Co-efficient**	**t-value**	**Significance**	**Co-efficient**	**t-value**	**Significance**
Own land (ha)	390.975	5.760	0.000	320.241	3.680	0.001	1138.734	7.080	0.000
Rented-in land (ha)	49.858	0.710	0.483	123.329	0.950	0.345	1069.440	2.570	0.013
Agricultural capital ($ US)	0.288	1.600	0.114	0.841	2.400	0.019	0.139	0.940	0.350
Non-agricultural capital ($ US)	0.791	4.860	0.000	0.455	3.460	0.001	20140.155	9.660	0.000
Male earners (unit)	130.427	2.240	0.029	192.574	7.110	0.000	252.552	3.470	0.001
Female earners (unit)	151.628	2.340	0.022	188.406	2.220	0.030	389.961	4.530	0.000
Schooling of male worker (year)	4.472	0.460	0.647	21.201	3.520	0.001	27.470	2.290	0.025
Schooling of female workers (year)	44.997	1.720	0.091	40.833	1.390	0.171	35.168	3.210	0.002
Female-headed household (dummy, female head=1)	-84.997	-0.580	0.566	-296.158	-3.120	0.003	-14.025	-0.100	0.922
Receiving remittance from domestic migrants (dummy, : yes=1, no=0)	721.202	4.620	0.000	152.040	2.300	0.025	226.651	2.520	0.014
Receiving remittance from overseas migrant (dummy: yes=1, no=0)	2764.936	2.820	0.006	1542.528	6.090	0.000	2455.575	13.350	0.000
Have access to electricity (dummy; yes=1, no=0)	291.726	2.510	0.015	214.773	2.560	0.013	341.942	4.540	0.000
Flood-prone ecosystem (dummy=1; yes=1, no=0)	-31.477	-0.370	0.716	-104.417	-1.350	0.182	-331.607	-2.720	0.009
Saline coast (dummy=1; yes=1, no=0)	-170.962	-1.280	0.204	4.780	0.040	0.969	-419.808	-3.340	0.001
	N=1231	R^2=0.678		N=1872	R^2=0.675		N=2846	R^2=0.750	

Table 10: Changes in incidence of poverty (percent/year)

Agro-ecology	Head-count index		
	1988-2014	1988-2000	2000-2014
Favourable	-2.1	-2.3	-1.9
Flood prone	-1.1	-1.5	-0.8
Coastal	-1.9	-2.5	-1.4

Table 11: Status of electricity connection with household

Agro-ecology	1988	2000	2014
Favourable	25.8	51.4	63.9
Flood-prone	11.2	22.0	55.0
Coastal	23.0	38.5	67.9
Total	21.0	40.3	62.1

Table 12 Multinomial logistic regression analysis of maternal BMI by seasonality and agro-ecological zones

		underweight		**overweight**			
		OR*	**95%CI**	**OR***	**95%CI**	χ^2	**p**
Seasonality	Post-Aman harvest	0.91	0.84-0.99	0.99	0.87-1.12	4.78	ns
	Post-Aus harvest	0.97	0.89-1.06	1.03	0.91-1.17		
	Monsoon (Ref)						
Geography	Coastal belt	1.38	1.17-1.62	0.89	0.72-1.11	66.26	<0.001
	Eastern hills	0.51	0.44- 0.58	1.13	0.95-1.35		
	Sylhet Haor	1.43	1.25-1.65	0.69	0.55-0.87		
	Flood plains	1.01	0.90-1.14	0.99	0.84-1.17		
	Other parts (Ref)						

Ref=Reference group

*Socio-economic and demographic information controlled for in the analysis were residence, education and occupation of the women and the main earner, wealth index, dietary diversity group, age and period of survey.

Table 13 Binary Logistic Regression Analysis of Z-scores by seasonality and agro-ecological zone

		HAZ				WHZ			
		OR*	95%CI	χ^2	p	OR*	95%CI	χ^2	p
Seasonality	Post-Aman harvest	1.04	0.96-1.12	2.19	ns	0.74	0.66-0.83	34.31	<0.001
	Post-Aus harvest	1.06	0.98-1.15			0.76	0.68-0.85		
	Monsoon (Ref)								
Birth-season	Post-Aman harvest	1.05	0.97-1.14	1.51	ns	0.97	0.86-1.09	0.55	ns
	Post-Aus harvest	1.05	0.96-1.13			1.01	0.90-1.13		
	Monsoon (Ref)								
Geography	Coastal belt	1.09	0.97-1.22	82.37	<0.001	0.97	0.82-1.15	1.77	ns
	Easten hills	0.93	0.82-1.05			0.83	0.70-0.99		
	Sylhet Haor	1.54	1.39-1.70			1.01	0.87-1.18		
	Flood plains	1.00	0.92-1.08			1.06	0.95-1.19		
	Other parts (Ref)								

Ref=Reference group,

*Socio-economic and demographic information controlled for in the analysis were residence, education and occupation of parents, dietary diversity group, wealth index, age and period of survey.

Figure 1 Percentages of undernourished children according to three rounds of data collection

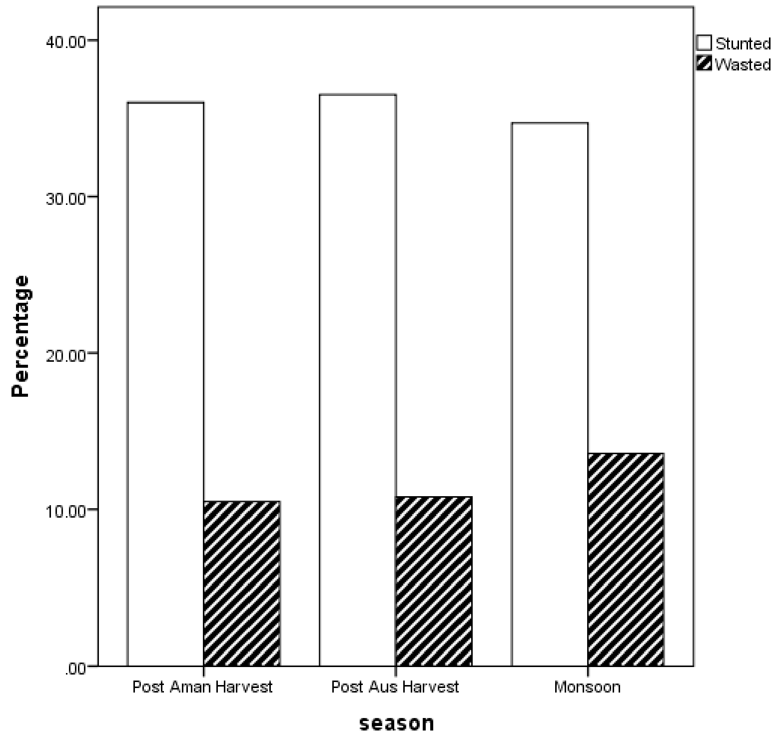


Figure 2 Percentages of BMI categories of mothers according to agro-ecological zone

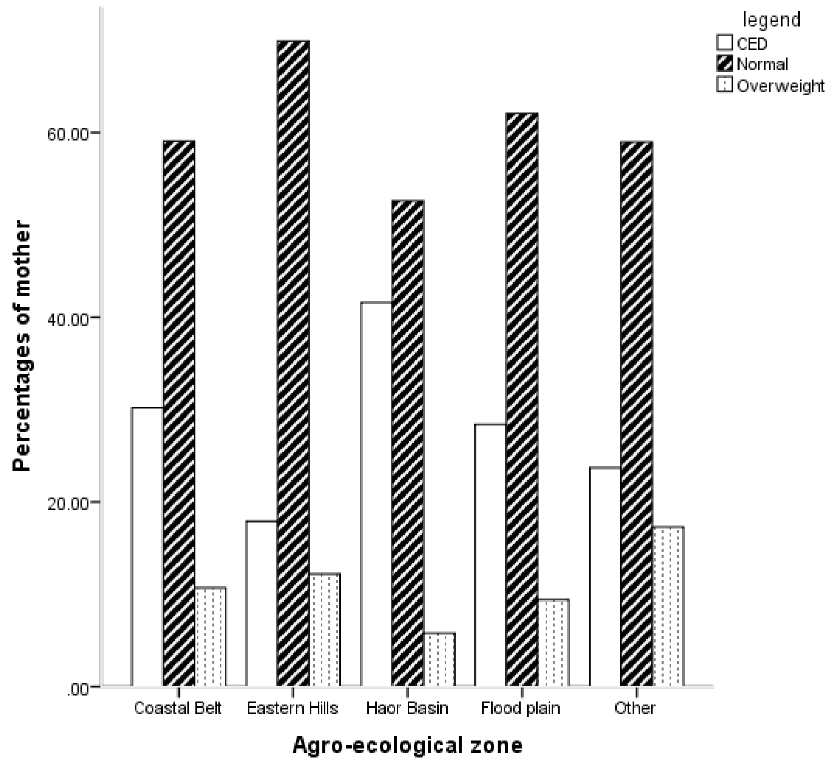


Figure 3 Percentages of undernourished children according to agro-ecological zones

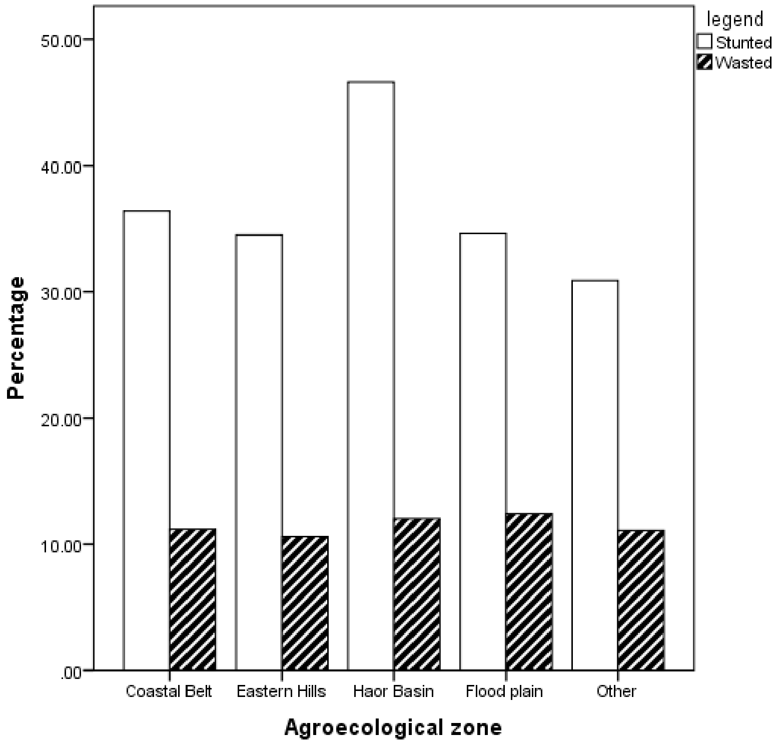


Figure 4 Mean HAZ of children according to their month of birth

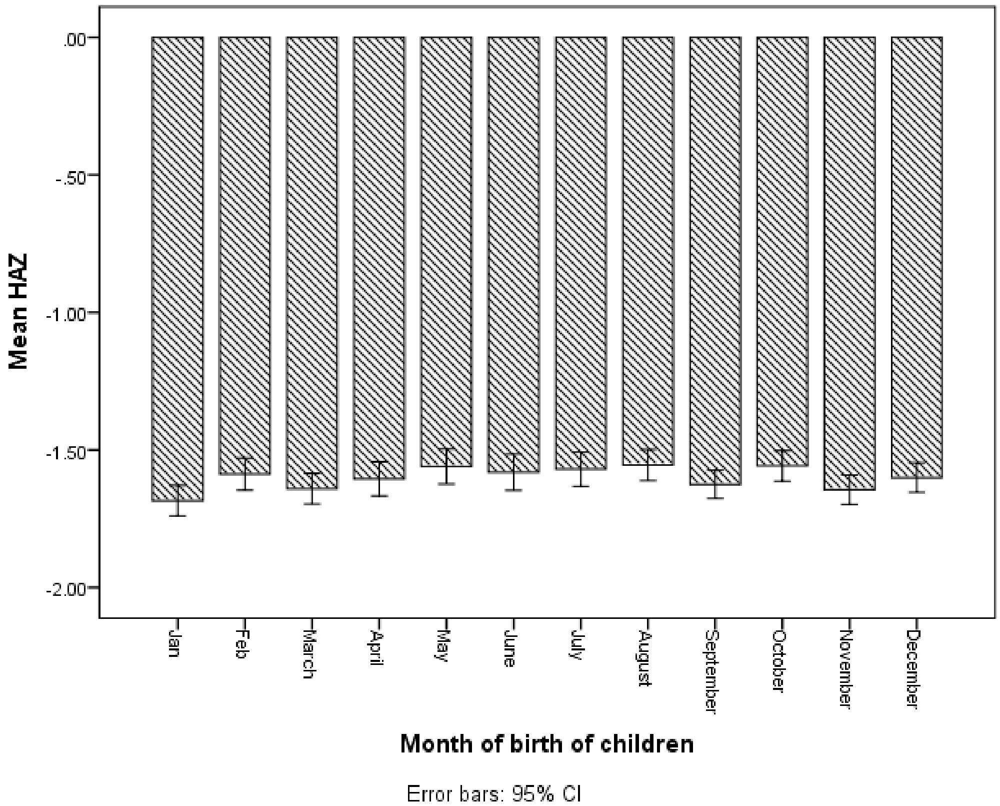
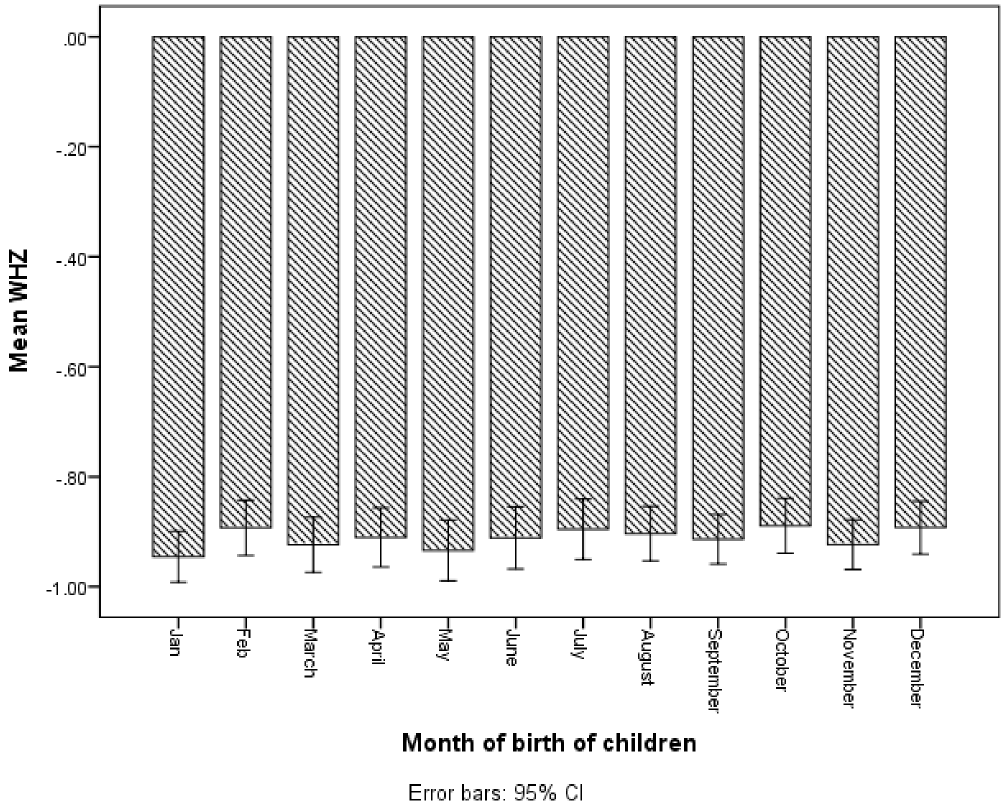


Figure 5 Mean WHZ of children according to their month of birth



References

Allen LH, Black AK, Backstrand JR, Pelto GH, Ely RD, Molina E & Chávez A. (1991). An Analytical Approach for Exploring the Importance of Dietary Quality Versus Quantity in the Growth of Mexican Children. Food and nutrition bulletin13, 95-104.

Balagtas JV, Bhandari H, Cabrera ER, Mohanty S & Hossain M. (2014). Did the Commodity Price Spike Increase Rural Poverty? Evidence from a Long-Run Panel in Bangladesh. Agricultural Economics 45, 303-312.

Bredenkamp C, Buisman LR & Van de Poel E. (2014). Persistent Inequalities in Child Undernutrition: Evidence from 80 Countries, from 1990 to Today. International journal of epidemiology 43, 1328-1335.

Chikhungu LC & Madise NJ. (2014). Seasonal Variation of Child under Nutrition in Malawi: Is Seasonal Food Availability an Important Factor? Findings from a National Level Cross-Sectional Study. BMC Public Health14, 1146.

Chowdhury NY & Christa R.(2014) Targetting the Poorest. In: Braun JV, Gatzweiler FW, editors. Marginality: Addressing the Nexus of Poverty, Exclusion and Ecology New York, London: Springer. p. 101-115.

Coates J, Swindale A & Bilinsky P (2007). Household Food Insecurity Access Scale (Hfias) for Measurement of Household Food Access: Indicator Guide (V. 3).Academy for Educational Development, Food and Nutrition Technical Assistance Project, Washington, D.C.

Dasgupta P & Mailer KG (1994). Poverty, Institutions and the Environment Resource Base. World bank Environment Paper no 9.World Bank, Washington DC.

Devereux S, Sabates-Wheeler R & Longhurst R.(2012). Seasonality Revisited: New Perspective on Seasonal Poverty. In: Devereux S, Sabates-Wheeler R, Longhurst R, editors. Seasonality, Rural Livelihoods and Development. New York, USA: Earthscan.

Duraiappah AK. (1998). Poverty and Environmental Degradation: A Review and Analysis of the Nexus World Development 26, 2169-2179.

Ferro-Luzzi A, Morris SS, Taffesse S, Demissie T & D'Amato M. (2002). Seasonal Undernutrition in Rural Ethiopia: Magnitude, Correlates, and Functional Significance.Food and nutrition bulletin23, 421-422.

Hasan MM, Ahmed S & Chowdhury MAH. (2013). Food Insecurity and Child Undernutrition: Evidence from Bdhs 2011. Journal of Food Security1, 52-57.

Headey D. (2013). Developmental Drivers of Nutritional Change: A Crosscountry Analysis. World Development 42, 76-88.

Hossain M (1998). Nature and Impact of the Green Revolution in Bangladesh. Research Report.International Food Policy Research Institute (IFPRI), Washington, D.C.

Hossain M. (2004). Rural Non-Farm Economy: Evidence from Household Survey.Economic and Political Weekly34, 4053-4058.

Hossain M. (2007). Technological Progress for Sustaining Food-Population Balance: Achievement and Challenges. Agricultural Economics37, 161-172.

Hossain M & Bayes A. (2009).Rural Economy and Livelihoods: Insights from Bangladesh. Bangladesh: A H Development Publishing House.

Janaiah A, Otsuka K & Hossain M. (2005). Is the Productivity Impact of the Green Revolution in Rice Vanishing? Economic and Political WeeklyXL.

Kandala N-B, Fahrmeir L, Klasen S & Priebe J. (2009). Geo-Additive Models of Childhood Undernutrition in Three Sub-Saharan African Countries. Population, Space and Place15, 461-473.

Kigutha HN, van Staveren WA, Veerman W & Hautvast JG. (1995). Child Malnutrition in Poor Smallholder Households in Rural Kenya: An in-Depth Situation Analysis. European journal of clinical nutrition49, 691-702.

Krugman P. (1999). The Role of Geography in Development. International Regional Science Review 22, 142-161.

Lin A, Arnold BF, Afreen S, Goto R, Huda TM, Haque R, Raqib R, Unicomb L, Ahmed T, Colford JM, Jr. & Luby SP. (2013). Household Environmental Conditions Are Associated with Enteropathy and Impaired Growth in Rural Bangladesh. The American journal of tropical medicine and hygiene89, 130-137.

Lokshin M & Radyakin S. (2012). Month of Birth and Children's Health in India.Journal of Human Resources47, 174-203.

Matin I, Parveen M, Das NC, Mascie- Taylor CGN & Raihan S (2009). Implications for Human Development - Impacts on Nutrition and Schooling. BIDS Policy Brief 3.BRAC and DFID, Dhaka, Bangladesh.

Miller J, Ritchie B, Tran C, Beggs S, Lada CO, Whetter K & Cobiac L. (2013).Seasonal Variation in the Nutritional Status of Children Aged 6 to 60 Months in a Resettlement Village in West Timor. Asia Pacific journal of clinical nutrition22, 449-456.

Nair KRG. (2007). Malnourishment among Children in India: A Regional Analysis.Economic and Political Weekly XLII.

Nestel PS, Mascie- Taylor CGN, Mohamed KA & Amin AEL. (1991). Nutritional Status of under Five Year Olds in North Sudan: Differences Due to Geographical Location, Age, Twin Status and Feeding Practices. Ecology of Food and Nutrition28, 87-103.

Ruben R, Pender J & Kuyvenhoven A. (2007).Sustainable Poverty Reduction in Less-Favoured Areas. Wallingford: CABI Publishing.

Rutstein S & Johnson K. 2004. The Dhs Wealth Index. DHS Comparative Reports No6.Calverton, Maryland USA: ORC Macro.

Salvador Castell G, Perez Rodrigo C, Ngo de la Cruz J & Aranceta Bartrina J. (2015).Household Food Insecurity Access Scale (Hfias). Nutricion hospitalaria31 Suppl 3, 272-278.

Slifkin R, Goldsmith L & Ricketts T. 2000. Race and Place:Urban-Rural Differences in Health for Racial and Ethnic Minorities NC Rural Health Research and Policy Analysis Program.

Spray AL, Eddy B, Hipp JA & Iannotti L. (2013). Spatial Analysis of Undernutrition of Children in Leogane Commune, Haiti. Food and nutrition bulletin34, 444-461.

Torlesse H, Kiess L & Bloem MW. (2003). Association of Household Rice Expenditure with Child Nutritional Status Indicates a Role for Macroeconomic Food Policy in Combating Malnutrition. The Journal of nutrition133, 1320-1325.

Torlesse H, Moestue H, Hall A, de Pee S, Kiess L & Bloem M.(2004). Dietary Diversity in Bangladesh: Evidence from the Nutritional Surveillance Project. In: Bouis H, Hassan N, Kabir K, editors. Alleviating Malnutrition through Agriculture in Bangladesh: Biofortifi Cation and Diversifi Cation as Sustainable Solutions Washington, D.C: IFPRI. p. 44-49.

Victora CG, de Onis M, Hallal PC, Blossner M & Shrimpton R. (2010). Worldwide Timing of Growth Faltering: Revisiting Implications for Interventions. Pediatrics125, e473-480.

WHO Expert Consultation. (2004). Appropriate Body-Mass Index for Asian Populations and Its Implications for Policy and Intervention Strategies.Lancet363, 157-163.

WHO Multicentre Growth Reference Study Group. (2006). Who Child Growth Standards Based on Length/Height, Weight and Age. Acta paediatrica (Oslo, Norway 1992) Supplement450, 76-85.

World Health Organization (WHO). (2000). Obesity: Preventing and Managing the Global Epidemic. Report of a Who Consultation. World Health Organization technical report series894, i-xii, 1-253.

Zug S. (2006). Monga - Seasonal Food Insecurity in Bangladesh - Bringing the Information Together. The Journal of Social Studies111, 1-14.

2013 Lancet series on Maternal and Child Undernutrition. (2013) Maternal and Child Nutrition: Building Momentum for Impact. Lancet382, 372-375

Appendix I

The process of selecting mother-child pairs with complete information from FSNSP data

Steps of selection	**FSNSP 2011**	**FSNSP 2012**
Total household	10415	10092
Had under five child in the family	10415	10092
Had child height, weight and age information	10411	10092
Calculation of Z-scores of (HAZ, WAZ and WHZ)	10325	9778
Excluded because Z-scores fall outside WHO cut-offs	10292	9744
Had maternal height and weight information	9703	9272
Had socio-economic and demographic variables	9364	8667
Had all variables	9279	8433
Included in the analysis	**17712**	

Appendix-II

Growth and structure of rural income

Income sources	Income share (%)								
	Year 1988			Year 2000			Year 2014		
	Favourable	Flood prone	Coastal	Favourable	Flood prone	Coastal	Favourable	Flood prone	Coastal
N=	617	357	257	945	537	390	1409	842	595
Agriculture	56.3	56.0	57.0	44.1	45.5	34.2	40.2	37.5	29.8
Rice	26.0	22.8	27.1	16.7	17.6	11.4	11.5	11.4	5.8
Non-rice crop	10.1	6.0	4.9	11.9	6.1	2.9	10.9	7.6	7.0
Non-crop agriculture	9.0	12.5	11.3	10.5	15.1	15.4	12.6	12.7	12.8
Agricultural wage	11.3	14.7	13.8	4.9	6.7	4.6	5.2	5.9	4.3
Non-agriculture	43.8	44.0	43.0	55.9	54.5	65.8	59.8	62.5	70.2
Business	8.8	9.6	8.9	26.7	19.0	30.5	19.0	16.1	18.0
Service	15.9	16.9	19.0	11.7	12.5	15.3	9.1	6.7	12.1
Remittance	8.9	9.6	7.5	12.7	15.1	16.2	21.7	25.3	28.7
Service and remittance	24.8	26.5	26.4	24.4	27.7	31.5	30.9	32.0	40.8
Non-agricultural wage	10.2	7.9	7.6	4.8	7.8	3.8	8.7	12.0	9.7
Transfer	-	-	-	-	-	-	1.2	2.3	1.6
Household	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Per capita income									

Appendix-III

The regression model is as follows:

INCHH = f (OLND, RLND, AGCPTL NAGCPTL, MEARN, FEARN, MSCL, FSCL, FHHH, LREM, FREM, ELC, FLD, SCST)

Where,

INCHH = Household income (in USD)

OLND = Own land (ha)

RLND = Rented-in land (ha)

AGCPTL = Agricultural capital (in USD)

NAGCPTL = Non-agricultural capital(in USD)

MEARN= No. of male earners (unit)

FEARN= No. of female earners (unit)

MSCL= Schooling of male worker (year)

FSCL= Schooling of female workers (year)

FHHH= Female headed household (dummy: yes=1, no=0)

LREM =Receiving remittance from domestic migrants (dummy: yes=1, no=0)

FREM= Receiving remittance from overseas migrant (dummy: yes=1, no=0)

ELC= Have access to electricity (dummy; yes=1, no=0)

FLD= Flood-prone ecosystem (dummy, flood prone=1)

SCST = Saline coast (dummy, Saline coast =1)

Appendix-IV

Growth and structure of rural income

Income sources	Average income (US $)								
	Year 1988			Year 2000			Year 2014		
	Favour able	Flood prone	Coa stal	Favour able	Flood prone	Coa stal	Favour able	Flood prone	Coa stal
N=	585	555	629	519	467	461	971	790	696
Agriculture	270	226	299	197	180	153	278	239	135
Rice	105	60	54	141	63	38	263	159	162
Non-rice crop	94	124	124	124	155	207	304	267	299
Non-crop agriculture	117	145	152	57	69	62	125	125	100
Agricultural wage	455	436	474	658	558	887	1441	1315	1636
Non-agriculture	91	95	98	314	195	411	458	340	420
Business	165	167	209	138	129	206	221	142	283
Service	92	95	82	150	155	218	524	533	668
Remittance	257	262	291	288	284	425	744	675	951
Service and remittance	106	79	84	56	80	52	209	253	226
Non-agricultural wage	1039	991	1103	1177	1025	1349	29	48	38
Transfer	-	-	-	-	-	-	2411	2105	2332
Household	172	171	180	246	193	245	612	492	561
Per capita income									

Appendix-V
Incidence of poverty

Poverty Measures (%)	Head-count index (per cent of households)								
	Year 1988			Year 2000			Year 2014		
	Fav our able	Flood prone	Coas tal	Favoura ble	Flood prone	Coas tal	Favoura ble	Flood prone	Coas tal
Head-count index	62.2	60.8	55.3	47.1	51.0	40.8	36.2	45.4	33.4
Extreme	35.3	34.7	28.0	20.5	20.7	18.5	5.5	5.9	4.5
Moderate	26.9	26.1	27.2	26.6	30.4	22.3	30.7	39.4	28.9
Poverty-gap index	27.2	25.7	21.2	18.3	20.0	15.5	12.6	15.7	10.5
Squared poverty-gap index	14.7	14.3	10.2	9.5	10.7	8.1	6.3	7.7	5.2